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REPORT

Adoption and Diffusion of Innovative Irrigation and Drainage Management Technologies and Practices: A Sociological Perspective

Prepared for the

San Joaquin Valley Drainage Program
2800 Cottage Way
Sacramento, CA 95825-1898

Under

U.S. Bureau of Reclamation
Contract 7-CS-20-05200

Prepared by

Kristi M. Branch
Gregory A. Poremba

August 1990

Battelle

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August 1990

This report presents the results of a study conducted for the Federal-State Interagency San Joaquin Valley Drainage Program. The purpose of the report is to provide the Drainage Program agencies with information for consideration in developing alternatives for agricultural drainage water management. Publication of any findings or recommendations in this report should not be construed as representing the concurrence of the Program agencies. Also, mention of trade names or commercial products does not constitute agency endorsement or recommendation.

The San Joaquin Valley Drainage Program was established in mid-1984 as a cooperative effort of the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources. The purposes of the Program are to investigate the problems associated with the drainage of irrigated agricultural lands in the San Joaquin Valley and to formulate, evaluate, and recommend alternatives for the immediate and long-term management of those problems. Consistent with these purposes, Program objectives address the following key areas: (1) Public Health; (2) Surface- and Ground- Water Resources; (3) Agricultural Productivity; and (4) Fish and Wildlife Resources.

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EXECUTIVE SUMMARY

The San Joaquin Valley Drainage Program is engaged in a comprehensive effort to solve problems related to agricultural drainage in the westside of the San Joaquin Valley. Among other options being considered is the introduction of beneficial technological innovations. A significant difficulty in assessing the longer-term social consequences of efforts to solve the drainage problem is our inability to model the adoption and diffusion of irrigation and drainage management practices under different institutional and policy conditions. This paper presents a a brief overview of the sociological literature on the diffusion and adoption of agricultural innovations and suggests an approach that could be used to evaluate the likelihood that different recommended irrigation and drainage management innovations will be adopted and to assess the impacts of those innovations on farm operations of different types. This paper was developed to aid the formulation of a survey of farm operations in areas on the westside of the San Joaquin Valley with high variation in shallow water table depth (Dinar and Campbell forthcoming). This survey obtained information about the irrigation and drainage reduction practices used on farm with varying conditions of salinity, soil type, cost of water, and the severity of drainage problems, with the objective of developing an analytic framework to estimate choices of irrigation technologies and drainage reduction practices.

In general, the sociological literature on agricultural innovation views the adoption of innovations as a decision-making process that is influenced by a variety of factors, including: (1) the social, institutional, and political context; (2) characteristics of the farm; (3) characteristics of the decision maker, usually represented by the owner or manager; and (4) characteristics of the technology/innovation. A central focus in the sociological literature has been to identify factors that influence the pattern of adoption of a particular innovation. This literature provides little information on the patterns that result when farm owners/managers are faced with the task of choosing among a variety of recommended alternative innovations. Consequently, the paper presents a methodology that could be used to make a preliminary evaluation of recommended irrigation and drainage management innovations in terms of their likelihood of adoption on different types of farm operations. The paper also discusses the use of a technique called "backward mapping" in the analysis of policies and strategies to encourage the adoption and diffusion of recommended irrigation and drainage management innovations.

1.0 INTRODUCTION

The San Joaquin Valley Drainage Program is engaged in a comprehensive effort to solve problems related to agricultural drainage in the westside of the San Joaquin Valley. Among other options being considered is the introduction of beneficial technological innovations. A significant difficulty in assessing the longer-term social consequences of efforts to solve the drainage problem is our inability to model the adoption and diffusion of irrigation and drainage management practices under different institutional and policy conditions.

At present, information is only partially available to answer such key questions as:

1. How quickly, on an acreage or percent of water use/drainage production basis, will recommended innovations be adopted?
2. What can be done to speed up the adoption of beneficial innovations? How will such interventions affect the distributional patterns of adoption among farm types?
3. Will recommended innovations be adopted more quickly on some types of farm than on others, and if so, will later adopters incur important disadvantages?
4. How will policies that enhance adoption of recommended water and drainage management techniques support or counteract other policy objectives?
5. What role do the key water management institutions -- U.S. Bureau of Reclamation (USBR), State Water Department (SWD), State Water Resources Control Board (SWRCB), and Water Utility Districts -- play in the adoption process?

As an initial step in addressing this problem, this report suggests a conceptual model of the decision-making process of farm operators and reviews the factors affecting agricultural land-managers' decisions about irrigation and drainage management that are identified in the sociological literature on adoption and diffusion of agricultural technologies.

This report reviews the factors that have been found to be of primary importance in farm owners'/managers' decision-making processes. It then proposes a conceptual model of the adoption process and a set of matrices for evaluating innovative irrigation and drainage technologies and management practices that might be recommended as partial solutions to the drainage problems in the San Joaquin Valley. The model is then used to outline the type of analysis that could be undertaken to evaluate policies and strategies designed to encourage adoption and diffusion of these innovations. Based on this examination, key uncertainties and unanswered questions are identified.

A survey conducted by Ariel Dinar and Mark Campbell (forthcoming) was designed to further articulate this model and obtain empirical information about the relationships among farm structure, management, and irrigation and drainage technologies.

2.0 CONCEPTUAL MODELS OF THE ADOPTION DECISION-MAKING PROCESS

The decision-making process followed by people during their daily activities is a complex interaction between data collection, interpretation, evaluation, and response or action. It is now recognized by many researchers that decision making is not a one-time event, but instead involves an iterative process of data collection and response (Earle 1987:28-29). People continually collect information (sometimes inaccurate or incomplete) about events that are occurring around them, paying special attention to information they feel may affect their immediate and future situation. They use a variety of logical, heuristic, and emotional processes to interpret these data and give it meaning (numerous examples exist of the same data being used by people who draw different conclusions), as well as to evaluate its importance relative to other events and information. Based on this interpretation and evaluation, they take action, defer taking action (for a variety of reasons, including the collection of additional information), or cease paying attention to the problem and information. It is also important to note that individual decision making is influenced to varying degrees by the actions and policies of other individuals and organizations (Clarke 1988, Ruttan 1989, Coughenour and Chamala 1989). However, the mandate for this study was to focus on factors that influence farm-level decisions, rather than on factors that influence the decisions and actions of other individuals and organizations (such as the state legislature or the State Water Resources Control Board (SWRCB)).

This general, iterative model of decision making can be used to examine decisions by farm owners and managers. Farmers continually monitor crop prices to determine what to plant and when to sell their commodities, they assess their assets and liabilities to determine whether to purchase or lease land and equipment, and they monitor land and soil characteristics to determine when fertilization, herbicides, pesticides, and water are needed. They also assess the capability of the infrastructure to expedite implementation of new technologies or methods to determine how much administrative and regulatory "hassle" is involved in undertaking the innovation. These decisions are complex and iterative, making it difficult to identify the specific combination of factors affecting a particular decision and to determine their relative importance. Indeed, efforts to identify and weigh such factors have been the focus of economic, social, and psychological research for many years. A brief summary of this research is presented in the following sections.

2.1 Theories About the Adoption of Agricultural Innovations

Research on the adoption of agricultural innovations has focused on the identification of factors that slow down or inhibit the adoption of innovations and on social, economic, or cultural factors that influence the pace of adoption. Frequently, implicit in this research is the assumption that the innovations studied are in fact beneficial ("good") and "should" be

adopted by farmers. There is a danger in this approach, however, as retrospective studies have shown that many recommended innovations have not proven uniformly beneficial. Research that reports the number and percentage of farms (or acreage) adopting and discontinuing innovations annually over time is particularly valuable. Such data provide the basis for identifying patterns in the pace of adoption for different technologies, institutional settings, and farm types. A number of studies (Griliches 1957, Mansfield 1961, and Fishelson and Rymon 1986, as discussed in Dinar and Campbell (forthcoming)), have demonstrated that the pattern of adoption over time follows a sigmoid (s-shaped) path. Data that could help predict the time path of the adoption/diffusion of recommended technologies and management practices in the western San Joaquin Valley would be useful in refining forecasts of future social, economic, and environmental conditions in this area and highlighting effective intervention policies and strategies.

A review of the literature identifies four major perspectives or approaches to the study of adoption of agricultural innovation. The **diffusion perspective** views adoption as being driven by the amount of information and the information dissemination networks existing in any particular area. In general, it is believed that increasing numbers of farm owners and managers adopt new technologies and practices as more information becomes available about the benefits of adoption and about the absence of detrimental effects of adoption. This process is facilitated by the existence of strong informational dissemination networks (e.g., information exchange between owners/managers, existence and activities of Cooperative Extension and other agencies, classes and seminars, and computers and databases), with more wealthy and educated farm owners and managers adopting early because of their more central role in the dissemination network.

The **economic constraint perspective** views adoption as being limited by banks' monetary and loan policies, farm assets and liabilities, and the cost and return on investment of the innovation. Once again, the innovations studied are generally assumed to be beneficial. This perspective holds that innovations are evaluated primarily upon the economic benefits that will be realized by the farm operation as a result of the innovation. Feder, Just, and Zilberman (1985) and Thirtle and Ruttan (1987) present reviews of the economic literature on adoption and diffusion of innovative technologies. This literature indicates that the likelihood of adopting an innovation increases in response to an increase in either farm inputs or outputs (Dinar and Campbell forthcoming).

The **value rational perspective** places primary importance on the values of the farm owner/manager and how those values affect decisions to implement an innovation. This perspective assumes that information about an innovation is available to the decision-maker, that this information is first evaluated rationally/logically by the farmer to determine its objective (especially economic) merits, and that it is then subjected to evaluation by the farmer's value system before a final decision is made to implement the innovation. The farmer may use commercially, technically, environmentally, or traditionally-oriented values to

decide whether or not to implement an innovation. Thus, one determines whether a farm will adopt an innovation by determining what values the farmer has and what qualities the innovation has, comparing the two, and judging which values will be given priority over others for the particular adoption decision being made.

Finally, from the conflict perspective, innovations are used to maintain or increase a farmer's power and status over other farmers by increasing productivity, thereby increasing farm income, assets, and the ability to increase the size and extent of operations. Thus, an innovation is not used because of its technical or economic merit, per se, but for its ability to contribute to the farmer's status and power. The innovation becomes a means to a greater goal, with the goal being the important determinant. This suggests that similar types of innovations, such as methods of irrigation, may not be compared with each other but with the merits of seemingly unrelated activities, such as participating in political activities or other status-enhancing opportunities.

2.2 Factors Affecting Adoption of Irrigation and Drainage Technologies

Within each of these four schools of thought, the research has identified variables (factors) that were correlated with the adoption of agricultural innovations. Several features or characteristics of the innovation itself have been found to be related to adoption, as have a variety of personal and social characteristics of the farmer.

Innovations that were the least complex, the most compatible with existing practices, and that decreased labor requirements were found to be adopted the most quickly (Fliegel and Kivilin 1962). Dillman, Beck, and Carlson (1987:347) found that the rate of adoption of no-till technology in eastern Washington and western Idaho was significantly hindered by innovations that were relatively costly and that introduced a new set of problems the farmer had to address. Fliegel and Kivilin (1962) suggest that the labor-saving properties of some innovations may have received unwarranted emphasis in the decision-making process, relative to the importance of other facets of the innovations. Farm owners/managers may become overwhelmed by the complexity involved in weighing all the available information and therefore may simplify the process by focusing on and adopting an innovation based upon the labor-saving features.

Personal and social characteristics of the farmer were also found to be related to adoption. Carlson and Dillman (1983:193) found that intergenerational kinship ties in farming (i.e., farming with one's children) and the likelihood of passing on the farm to offspring expanded the planning horizon for the operations in eastern Washington. Soil conservation innovations that would not provide short-term returns were implemented because of the long-term benefits that would be realized by the family member(s) taking over the operation. They also found that adoption levels were second highest for farming under other kinship arrangements (i.e., with other siblings or relatives) and the lowest for farms operating without kinship

arrangements. Van Es and Tsoukalas (1987) partially replicated the Carlson/Dillman study and found that adoption of soil conservation practices in Illinois also depended upon the perceived effects of the soil erosion problem on maintaining soil productivity.

Evidence about the effects of the farmer's age on their propensity to adopt is mixed. Carlson and Dillman (1983:194) and Yarbrough and Scherer (1984:12) found the age of the farmer to be inversely related to adoption of innovative soil conservation practices. However, Dillman, Beck, and Carlson (1987:349) found there was no relationship between age and adoption for till and no-till farmers in the same geographic area.

A large amount of research has been conducted about the effects of education and are less contradictory than the above findings. Albrecht and Ladewig (1984:13), Carlson and Dillman (1983:194), Dillman, Beck, and Carlson (1987:349), Rogers (1983, as cited by Dillman, Beck, and Carlson (1987:343)), and Yarbrough and Scherer (1984:12) found the educational level of the farmer to be positively related to adoption. In a partial review of the literature, Albrecht and Ladewig (1984:7) also found that research conducted by Ajaga (1980), Beal and Sibly (1967), Carlson et al. (1980), Nowak and Korsching (1982), and Rogers and Shoemaker (1971) supported the positive relationship between education and adoption. Such overwhelming evidence leaves little doubt that education is a major factor in adoption.

Farm owners' and managers' values and perceptions of farming have also been found to have an effect on the rate of adoption of agricultural innovations (Dillman, Beck, and Carlson 1987:347). For example, farmers were found to value minimum amounts of residue and weeds in their fields. In other words once the crop was harvested, a farmers' status was partially enhanced by having fields that were barren. Thus, implementing new no-till techniques that left significant amounts of residue in the field required a major value-shift for area farmers.

There is research that suggests that some farmers may have a general propensity toward experimenting with new technologies and, therefore, adopting innovations. Dillman, Beck, and Carlson (1987:349; also see Feller et al. (1984), as cited by Dillman, Beck, and Carlson (1987:360)) found that some of the earliest users of no-till were "inventors," who had built drills from scratch on their own farms or modified previously built drills. In addition, they found that the earliest users of the no-till technology scored higher than other farmers on a "mechanical aptitude" score while the scores of each successive group of adopters decreased (1987:351). This provides a different perspective on adoption than is usually portrayed in the adoption literature. Usually the innovation is assumed to be introduced by some "outside" source and then to be adopted by farmers, sometimes with minor modifications. There are strong indications, however, that farmers can themselves be the inventors and innovators, who not only inform other farmers about the innovation but also those "outsiders." Along this line, Nowak et al. (1984:3) found only one personal characteristic positively related to adoption -- personal propensity to take risks.

Willingness to adopt innovations has been found to be affected by the characteristics and success (economic well-being) of the farm operation. A positive relationship has been found between farm income and adoption by Carlson and Dillman (1983:194), Rogers (1983; as cited by Dillman, Beck, and Carlson (1987:343)), and Yarbrough and Scherer (1984:12). In contrast, Nowak et al. (1984:3) found that in Iowa, gross farm income which they used as a measure of operation scale, was inversely related to the adoption of Best Management Practices (BMP) and use of credit was positively related to BMP adoption.

Some research has been conducted about the sources of income of a farm and its relationship to adoption of agricultural innovations. The portion of farm household income derived from the agricultural operation and from off-farm employment is an indication of the diversity of the economic base of the operation and could indicate the potential success of the operation during poor economic conditions. Yarbrough and Scherer (1984:12) found a weak positive relationship between off-farm employment and use of on-farm computers, and a weak negative relationship with use of off-farm computer services. Taylor and Miller (1978:642) found that 96 percent of the Amish farmers in their study (who were more likely to adopt environmentally-oriented innovations than non-Amish) reported farming as their primary occupation while only 53 percent of the non-Amish did so.

In addition, the freedom provided by a solid financial base of operation may allow a decision-making process that is based upon a different set of values than that of struggling farm operations. Fliegel and Kivilin (1966) found that prosperous farmers' who perceived an innovation as "rewarding," having little risk, and as directly enhancing their occupational interests were likely to adopt it quickly. The complexity of the innovation and the consequences of implementing it seemed to have no effect on adoption for this group.

Prosperity has also been equated with the size of the farm operation, under the assumption that the farmers who are successful will continue to add to their landholdings and operations. In their study of small and middle-scale dairy farmers in Pennsylvania, Fliegel and Kivilin (1967) found that small-scale farmers were slower to adopt innovations as a result of their scale of production and differences in perceptions about the innovation. Albrecht and Ladewig (1984:8,13) found in their own and others' research (Abd-Ella et al. 1981, Beal and Sibly 1967, Camboni and Napier 1984:17, Carlson and Dillman 1983:194, Carlson et al. 1980, Hooks et al. 1983, Napier et al. 1984, and Rogers and Shoemaker 1971) a positive relationship between the size of the farm operation and adoption (as did Rogers 1983, as cited by Dillman, Beck, and Carlson 1987:343; Dillman, Beck, and Carlson 1987:349; and Yarbrough and Scherer 1984:12). Thus, although research about the positive relationship between income and adoption is mixed, the positive relationship with the size of the farm is well supported.

Related to prosperity, research has indicated that farm ownership status is important in adoption. Albrecht and Ladewig (1984:8-9) cited several studies (Lasley and Nolan 1981, and Nowak and Korsching 1982) that showed landowners were more likely to be innovators than

farmers who rented land. This was partially attributed to the limited decision-making freedom available to renters. In addition, Albrecht and Ladewig (1984:14) found those who had adopted center-pivot sprinklers had a higher ratio of land-owned to total land-farmed than those who did not.

Economic conditions that are beyond the control of the farmer can also significantly affect the rate of adoption. Dillman, Beck, and Carlson (1987:345) found that high energy costs of the 1970s and rising labor costs were strong preconditions leading to the adoption of no-till machinery in the early 1980s. As is discussed below, this study also found the cost-saving characteristics of new irrigation technologies to be a major factor.

Other characteristics of the farm operations found to influence certain types of agricultural innovations include whether they irrigate their croplands and the source(s) of the irrigation water. Caswell and Zilberman (1985:230) and Camboni and Napier (1984:18) found the adoption of improved irrigation technologies was dependent upon the amount and types of commodities produced. For instance, "growers of almonds and pistachios have higher rates of adoption of sprinkler and drip irrigation than do grape growers ... [and] deciduous fruit growers [did] not differ significantly from grape growers." They also found that "farmers who apply groundwater are more likely to adopt sprinkler and drip technologies than are farmers who use surface water" (Caswell and Zilberman 1985:229). These differences were attributed to the higher cost of installing wells and pumps and operating the equipment on the farm, when compared to obtaining water from gravity-fed systems provided and subsidized by federal agencies and water districts.

Participation in information networks, access to farm magazines and journals, and exchanges between farm owners/managers have also been found to have positive effects on innovation adoption (Albrecht and Ladewig 1984:13; Caswell and Zilberman 1985:230; Dillman, Beck, and Carlson 1987:354; Fliegel 1965, as cited by Albrecht and Ladewig 1984:8; and Rogers and Shoemaker 1971, as cited by Albrecht and Ladewig 1984:8). Farmer interactions with and information from Cooperative Extension and U.S. Department of Agriculture (USDA) personnel (Nowak 1987) and the Soil Conservation Service (Dillman, Beck, and Carlson 1987:345) were also found to be important factors leading to the adoption of innovations. However, Yarbrough and Scherer (1984:16) are skeptical of studies that indicate that exchanges between farm owners/managers are primary information sources. Their study showed that mass media and expert sources were used much more often than interpersonal exchanges to obtain information before using computers for their operations.

Rogers (1983) (as discussed in Dillman, Beck, and Carlson 1987:343) and Dillman, Beck, and Carlson (1987:357) also found that owners/managers who travelled or telephoned more frequently to obtain information were likely to be among the first adopters of agricultural innovations. This is not surprising because actively travelling to obtain information indicates a strong interest, investment of time and funds, and therefore intent to implement an innovation.

Institutional factors outside the control of the farm owner/manager may help or hinder a farmer's adoption of innovative technologies/practices. Nowak et al. (1984:3) found a strong positive relationship between adoption and both institutional cost-sharing and the existence of a Soil Conservation Service (SCS) plan. On the other hand, Headley (1985) found that conflicts between the SCS and Cooperative Extension has sometimes led the two groups to promote opposing and mutually exclusive soil conservation practices. Such conflict may deter adoption because farmers do not want to be seen as taking sides in the political/ jurisdictional struggle and because conflicting information may increase the uncertainty about the benefits of each proposed option.

Labor conflicts and the influence of business ties with agribusiness corporations may also force the farmer to adopt innovations. Rosset and Vandermeer (1986) found that tomato canneries in Ohio pressured farmers to adopt mechanical harvesters in response to a farm labor strike. Use of mechanized harvesting equipment was further reinforced by its support from an educational institution and the Cooperative Extension Service, even though its benefits to the farmer were strongly questioned by others.

Finally, some environmental factors have been shown to be related to adoption of methods of irrigation. For instance, Albrecht and Ladewig (1984:14) found that farmers adopting center-pivot sprinklers and return pits were located in areas having greater saturated thickness (total depth of the aquifer). Adopters of center-pivot sprinklers were likely to receive significantly less precipitation than nonadopters. However, contrary to expectations, those adopting soil moisture detection methods were in areas that received significantly greater amounts of precipitation than nonadopters had received. It is not clear what intervening variables caused this unexpected result.

Another example of the effects of environmental factors is provided by Caswell and Zilberman (1985:230) who found that soil characteristics affected adoption of irrigation technologies. Farms with lighter soils (i.e. having higher rates of percolation) implemented more efficient irrigation technologies to decrease the amount of water that was applied, while maintaining rates of yield. This was interpreted as a decision based upon the economic importance of the cost of irrigation water as it related to soil characteristics.

Factors found to have little or no effect on the adoption of innovations on farms include the cost of innovation, ability to try the innovation on a trial basis, or the farmer's attraction to the mechanical properties of the innovation (Fliegel and Kivilin 1962 and 1966). The lack of importance of the cost of the innovation may be explained by other financial considerations. For instance, if the farm operation was fiscally sound and could afford the innovation, or if it could get the financing from a loan institution (McIntosh and Zey-Ferrell 1987) and the innovation was expected to afford a good return on the investment, it might be implemented regardless of cost. The lack of consensus on the definition of "trial basis" may contribute to

these findings. Farmers may decide to discontinue an innovation based on negative experience without necessarily labeling their adoption as a "trial."

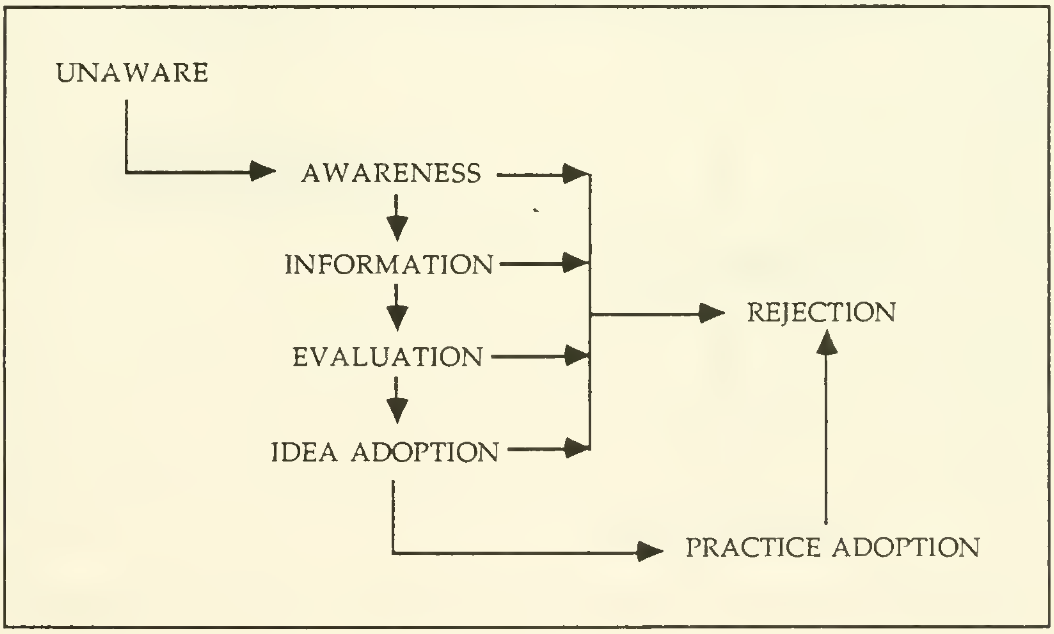
As the above literature shows, strong relationships exist between some independent variables and adoption of agricultural innovations while weak or mixed relationships have been found with others. The following section presents some of the models that have been developed to characterize the innovation adoption decision-making process and incorporates them into a model that could be used as a basis for examining the adoption of irrigation and drainage reduction and management innovations in the San Joaquin Valley.

2.3 Conceptual Models Presented in the Literature on the Adoption of Innovative Technologies and Management Practices

Several heuristic models have been developed to portray the decision making and adoption process of agricultural innovations. Three models were explicitly presented in the adoption literature and are presented below. All three models seem to be adaptations of the diffusion or the diffusion-economic constraint models, presented with varying amounts of detail, and with different pathways.

Yarbrough and Scherer (1984:5) developed a model, shown in Figure 1, to show the decision-making process that is assumed to take place when computers are adopted for use in agriculture.

Figure 1. Adoption of Computers for Agricultural Operations (Model 1)



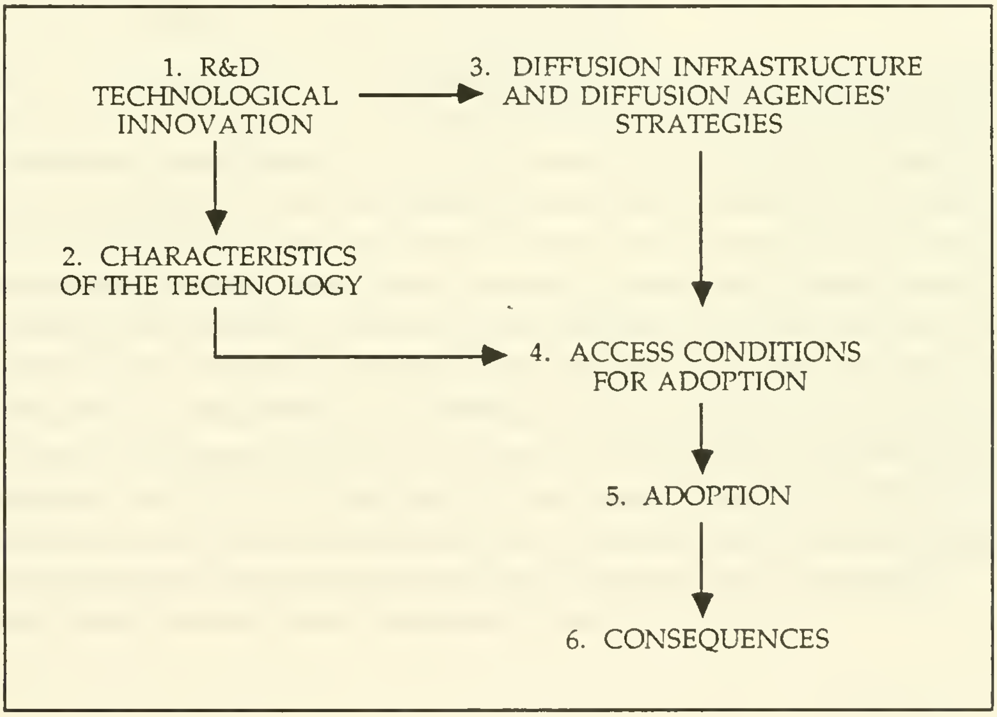
"The model assumes a linear progression through the stages of the model. It assumes that there is a pre-stage at which individuals are unaware of the innovation. At the awareness stage, the individual knows the innovation exists, but lacks detailed information about it. At

the information or interest stage, the individual begins to acquire detailed information about the innovation - what it is and how it works. At the evaluation stage, the individual weighs the pros and cons of the innovation and mentally applies it to his situation. Adoption involves both a commitment to acquire and use the innovation and its actual acquisition and use. We have divided these in our model. Rejection of the innovation is a possible decision outcome and can occur at any stage in the process" (Yarbrough and Scherer 1984:4-5).

Yarbrough and Scherer consider the process of adoption to be fairly slow (1984:6) and find that rejection usually occurs during the early phases of the process "without the benefits of detailed information or careful consideration [but] that over time these initial rejectors are likely to reconsider and reenter the decision process" (1984:7). Gross income, years of education, age, previous use of computers, and sophistication of the existing record-keeping and management practices were found to significantly affect the entire adoption process (1984:11). Off-farm employment was not significant.

Another model for the adoption of computers in farm operations, shown in Figure 2, relies much more heavily upon the characteristics of the technology and the information diffusion network that exists (Audirac and Beaulieu 1986).

Figure 2. Adoption of Computers for Agricultural Operations (Model 2)


1. R&D TECHNOLOGICAL INNOVATION
3. DIFFUSION INFRASTRUCTURE AND DIFFUSION AGENCIES' STRATEGIES
2. CHARACTERISTICS OF THE TECHNOLOGY
4. ACCESS CONDITIONS FOR ADOPTION
5. ADOPTION
6. CONSEQUENCES

In this model, the adoption process begins much earlier: the technology development (research and development) stage is included in the process. Once the technology has been

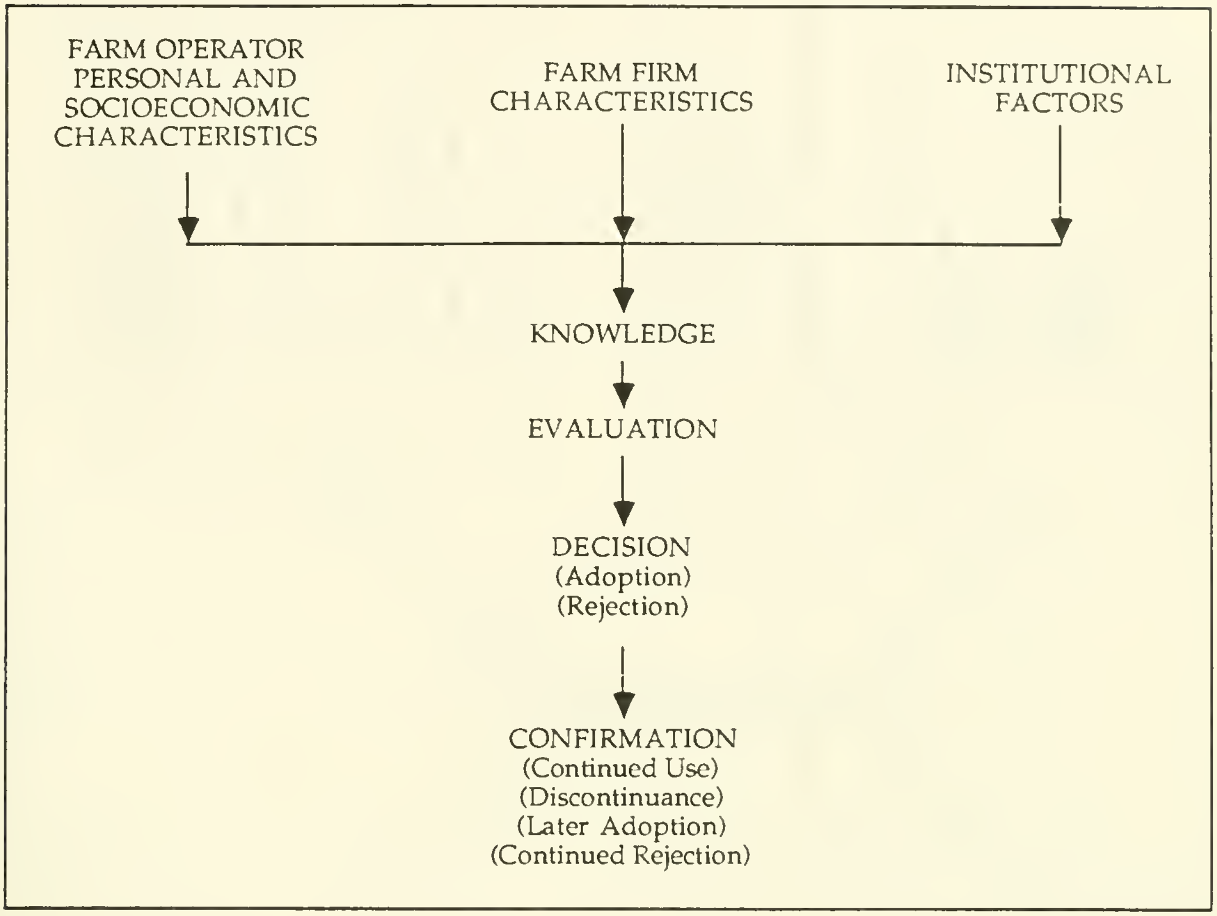
developed, the characteristics of the technology take on importance in the process. Audirac and Beulieu feel it is important to account for different attributes of potential innovations/technologies, particularly in terms of the type of benefits derived from their use. For example, in their model, computers would be characterized as providing information and decreasing the amount of time spent on management tasks (as opposed to new machinery that might be characterized as saving on physical labor). Marketing of the innovation by the manufacturer as well as other information diffusion networks then "not only influence but also define" whether a farm operator/manager will have access to the technology (via availability of information about the innovation).

These pre-defined conditions are then supplemented with the conditions of the farm operation--existence of tax deductions for purchases, "type and size of operation, amount of hired labor, level and kind of management, type and diversification of production, on and off farm income, level of mechanization, and marketing practices as well as its locational characteristics relative to dealers and public diffusion networks" (Audirac and Beaulieu 1984:19-20). If conditions are good the innovation (in this case computers) is adopted, but if there are adverse consequences to adoption it may be discontinued.

The most detailed model in the literature reviewed was based on Rogers and Shoemaker (1971), Nowak et al. (1984:2) This model, shown in Figure 3, was developed to describe adoption of Best Management Practices (BMPs) in agriculture.

Rogers and Shoemaker model best management practice adoption as basically a recursive, temporal process which begins with the farmer gaining some knowledge or awareness of the BMP. The farmer then evaluates how the BMP in terms of how it would fit into the farmer's operation and the benefits or costs (including risks) associated with adopting it. Based on this evaluation of the BMP, the farmer then decides to either adopt or reject the BMP. Over time, additional knowledge and experience either confirms or contradicts the initial evaluation. Based on this ongoing evaluation, the farmer either maintains the previous decision or takes a new course of action. The model postulates that the personal and socioeconomic characteristics of the farm operator, characteristics of the farming operation, the nature of the larger social system, types of communication channels and amounts of communications, and the perceived characteristics of the BMPs can all affect the adoption process (Nowak et al. 1984:2). It is noteworthy that none of these models explicitly includes values of the farm owner/manager among the independent variables influencing adoption decisions. Instead these models incorporate values implicitly, in the "evaluation" process.

Figure 3. Adoption of Best Management Practices (BMP) in Agriculture

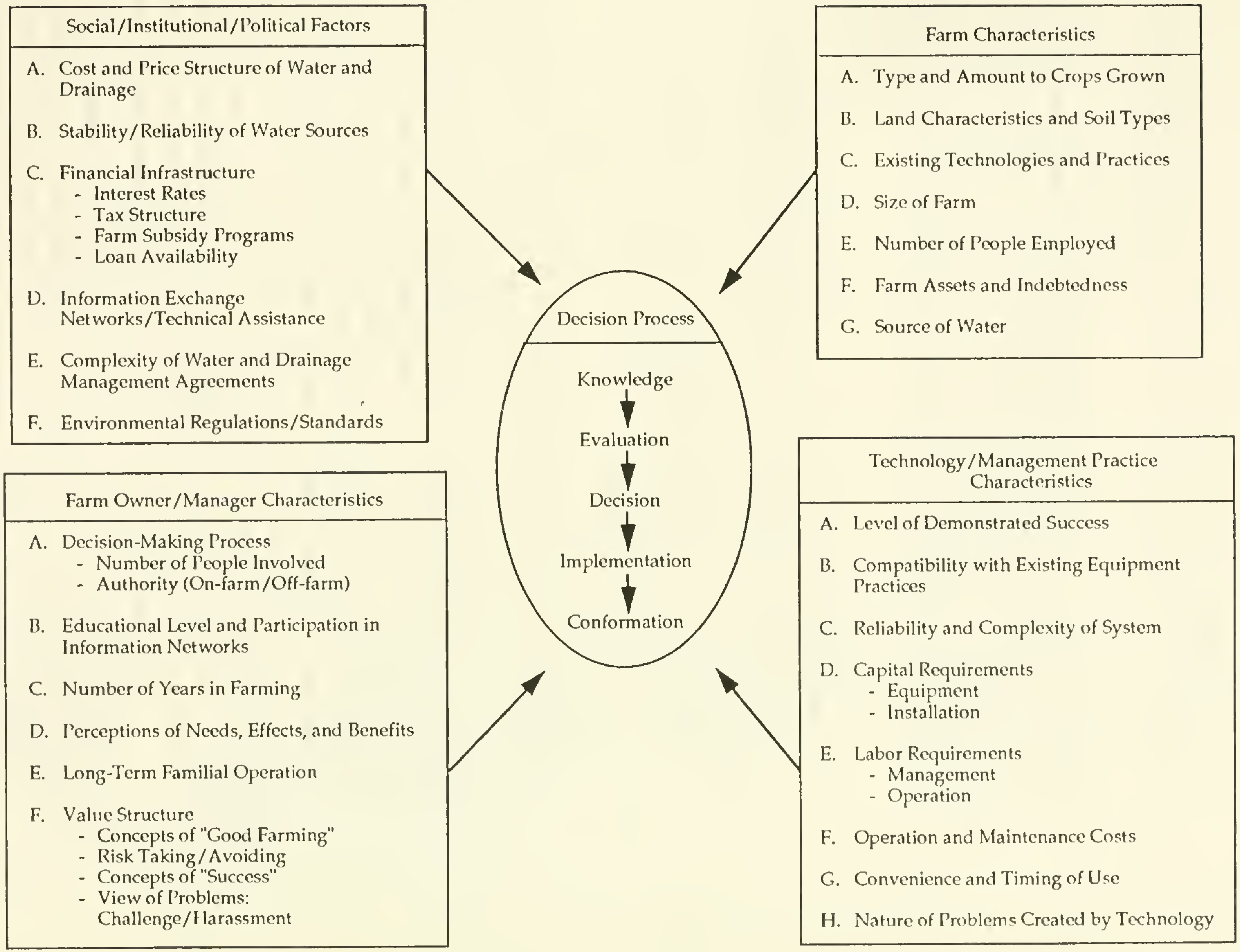


2.4 Proposed Conceptual Model for the Adoption of Innovative Irrigation and Drainage Reduction Technologies and Management Practices

The model we propose as a basis for clarifying the decision-making process concerning irrigation and drainage management innovations in the San Joaquin Valley is an elaboration of the Rogers and Shoemaker model. It provides a framework for identifying the primary factors that affect the decision-making process, showing how the decision-making process varies by the type of farm, and illustrates the decision-making process, including the strength of the pathways and how information exchange may occur among the four types of farm owner/managers.

We have grouped the primary variables of the model into four major components: social/institutional/political factors; technology/management practice characteristics; farm characteristics; and farm owner/manager characteristics as shown in Figure 4. As the following discussion shows, the variables in this model are highly interrelated and could be rearranged into several categories. The four components have been developed to facilitate discussion

Figure 4. Proposed Model of Primary Factors Influencing the Adoption of Irrigation and Drainage Reduction Technologies and Management Practices


Social/Institutional/Political Factors
A. Cost and Price Structure of Water and Drainage
B. Stability/Reliability of Water Sources
C. Financial Infrastructure
- Interest Rates
- Tax Structure
- Farm Subsidy Programs
- Loan Availability
D. Information Exchange Networks/Technical Assistance
E. Complexity of Water and Drainage Management Agreements
F. Environmental Regulations/Standards
Farm Characteristics
A. Type and Amount to Crops Grown
B. Land Characteristics and Soil Types
C. Existing Technologies and Practices
D. Size of Farm
E. Number of People Employed
F. Farm Assets and Indebtedness
G. Source of Water
Decision Process
Knowledge
Evaluation
Decision
Implementation
Conformation
Farm Owner/Manager Characteristics
A. Decision-Making Process
- Number of People Involved
- Authority (On-farm/Off-farm)
B. Educational Level and Participation in Information Networks
C. Number of Years in Farming
D. Perceptions of Needs, Effects, and Benefits
E. Long-Term Familial Operation
F. Value Structure
- Concepts of "Good Farming"
- Risk Taking/Avoiding
- Concepts of "Success"
- View of Problems: Challenge/Harassment
Technology/Management Practice Characteristics
A. Level of Demonstrated Success
B. Compatibility with Existing Equipment Practices
C. Reliability and Complexity of System
D. Capital Requirements
- Equipment
- Installation
E. Labor Requirements
- Management
- Operation
F. Operation and Maintenance Costs
G. Convenience and Timing of Use
H. Nature of Problems Created by Technology

rather than to definitively group variables. In the proposed model, all four categories of variables influence the decision-making process and are, therefore, important throughout the adoption/diffusion sequence.

We recommend an approach that places greater emphasis on the cumulative numbers and percentages of farms and acreage using recommended technologies and management practices over a more extended period of time rather than on determination/identification of early adopters. Too much emphasis on "early" adoption can divert attention from the development of effective, long-term policies and programs. For example, although size of farm has consistently been shown to be related to early adoption of innovation, there is substantial evidence that smaller farms show a high rate of adoptions, over time, though their pace of adoption is somewhat slower.

Dinar and Campbell (forthcoming) examine the hypothesis that farmers faced with pressing management problems are particularly prepared to adopt technologies and management innovations presented as effective or promising in addressing those problems. This raises interesting questions about farm owner/manager willingness to "try out" innovations earlier in the development of new technologies and management practices when those technologies/practices are specifically targeted to the problems they face, and about the influence of perceived problems on the selection and adoption of innovations.

Figure 5 illustrates potential differences between, and among, farmers managing different types of farm operations in the adoption of innovations that are less complex and divergent from existing practices. Figure 6 illustrates these differences for innovations that are complex and divergent from existing practices. The typology of farms shown in this figure is based on work conducted for the San Joaquin Valley Drainage Program (Branch and Poremba 1990), which identified four major types of farms in the westside of the San Joaquin Valley - the part-time/small farm, family-worked farm, family-business farm, and manager-operated subsidiary farm. The general characteristics of each type of farm operation are assumed to contribute to their particular use of the same decision-making processes. At this time it is unclear just what aspects of management and labor structure are most critical and whether there should be a distinction between family-worked farms and family-businesses farms. Therefore, a dashed line is placed between the two to signify that there may not be much of a distinction between them. Campbell and Dinar (forthcoming) are specifically examining the effect of farm management structures on the adoption of innovations in the San Joaquin Valley.

Figure 5 represents the adoption of less complex innovations and those innovations that are most compatible with existing equipment and farm practices. These innovations usually have less risk associated with them and are the easiest to implement. They are, therefore, more likely to be adopted quickly than are more complex and divergent innovations. Figure 6, though similar to Figure 5 in man aspects, assumes that hobby/small farm operations will not adopt complex and divergent innovations, and that family farms are not very likely to adopt

Figure 5. Hypothesized Sequence of Decision Making in the Adoption Process for Different Types of Farm Operations: Less Complex and Divergent Innovations

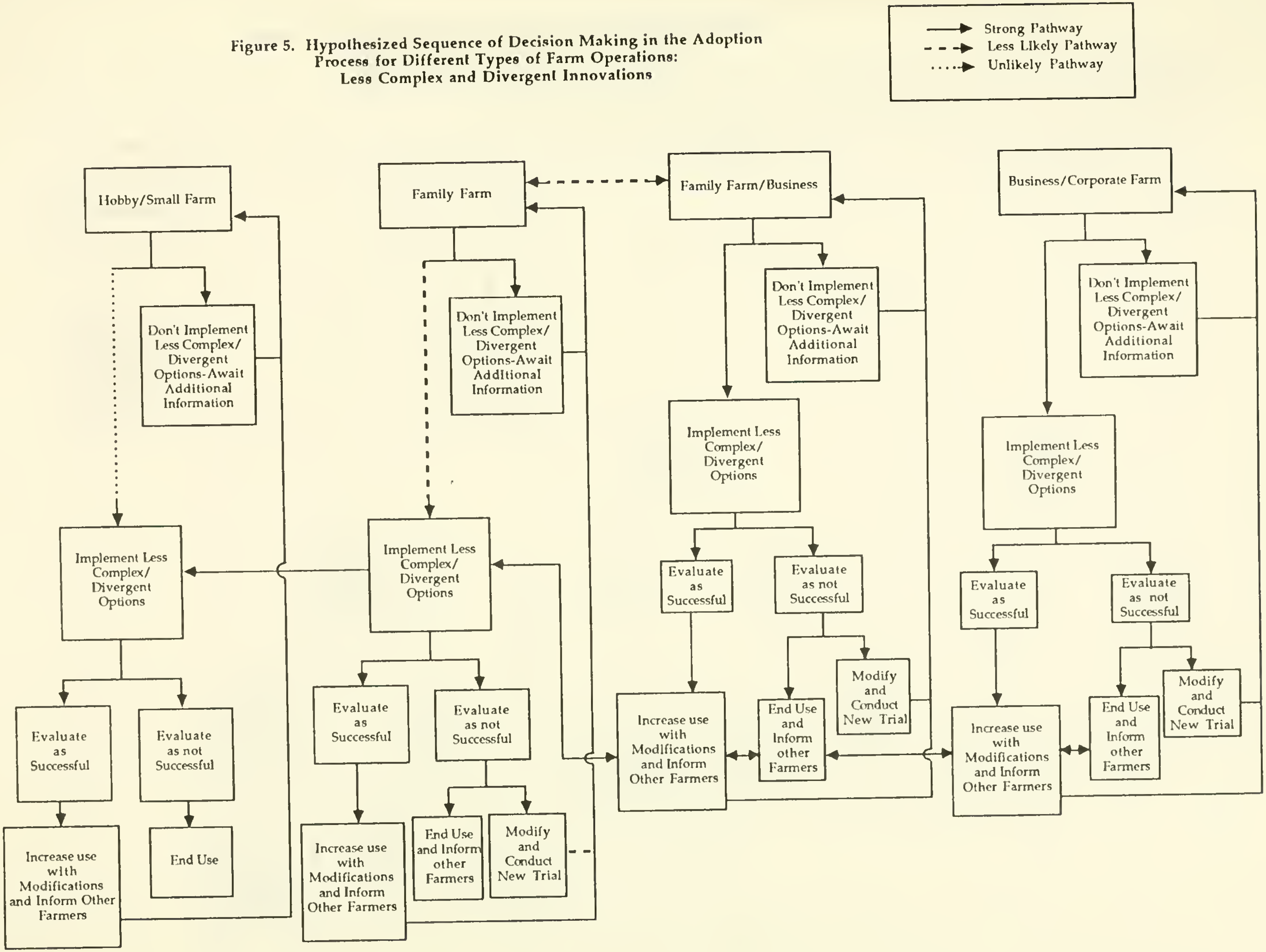
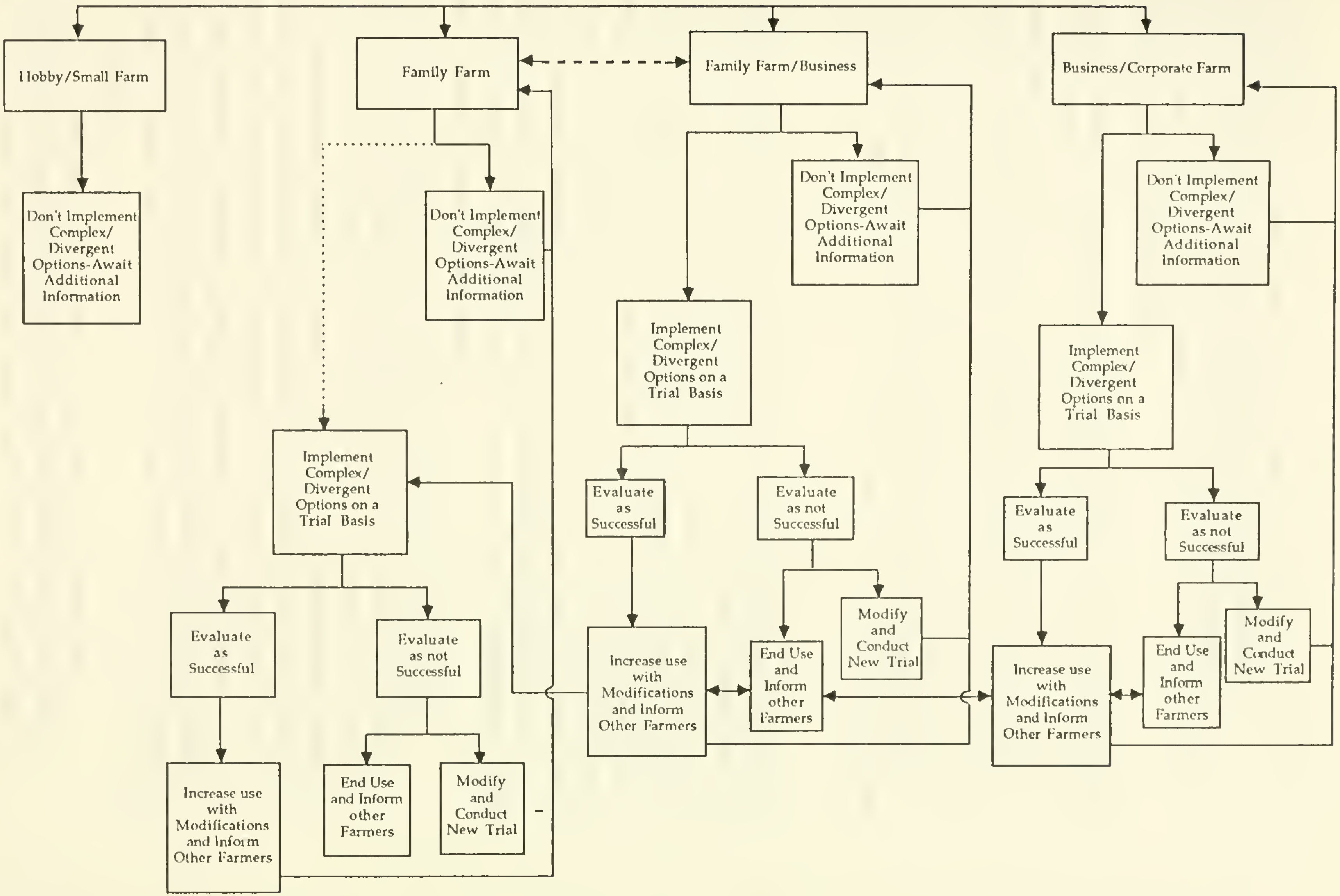

Strong Pathway
Less Likely Pathway
Unlikely Pathway
Hobby/Small Farm
Don't Implement Less Complex/ Divergent Options-Await Additional Information
Implement Less Complex/ Divergent Options
Evaluate as Successful
Evaluate as not Successful
Increase use with Modifications and Inform Other Farmers
End Use
Family Farm
Don't Implement Less Complex/ Divergent Options-Await Additional Information
Implement Less Complex/ Divergent Options
Evaluate as Successful
Evaluate as not Successful
Increase use with Modifications and Inform Other Farmers
End Use and Inform other Farmers
Modify and Conduct New Trial
Family Farm/Business
Don't Implement Less Complex/ Divergent Options-Await Additional Information
Implement Less Complex/ Divergent Options
Evaluate as Successful
Evaluate as not Successful
Increase use with Modifications and Inform Other Farmers
End Use and Inform other Farmers
Modify and Conduct New Trial
Business/Corporate Farm
Don't Implement Less Complex/ Divergent Options-Await Additional Information
Implement Less Complex/ Divergent Options
Evaluate as Successful
Evaluate as not Successful
Increase use with Modifications and Inform Other Farmers
End Use and Inform other Farmers
Modify and Conduct New Trial

Figure 6. Hypothesized Sequence of Decision Making in the Adoption Process for Different Types of Farm Operations: More Complex and Divergent Innovations


Strong Pathway
Less Likely Pathway
Unlikely Pathway
Hobby/Small Farm
Don't Implement Complex/ Divergent Options-Await Additional Information
Family Farm
Don't Implement Complex/ Divergent Options-Await Additional Information
Implement Complex/ Divergent Options on a Trial Basis
Evaluate as Successful
Evaluate as not Successful
Increase use with Modifications and Inform Other Farmers
End Use and Inform other Farmers
Modify and Conduct New Trial
Family Farm/Business
Don't Implement Complex/ Divergent Options-Await Additional Information
Implement Complex/ Divergent Options on a Trial Basis
Evaluate as Successful
Evaluate as not Successful
Increase use with Modifications and Inform Other Farmers
End Use and Inform other Farmers
Modify and Conduct New Trial
Business/Corporate Farm
Don't Implement Complex/ Divergent Options-Await Additional Information
Implement Complex/ Divergent Options on a Trial Basis
Evaluate as Successful
Evaluate as not Successful
Increase use with Modifications and Inform Other Farmers
End Use and Inform other Farmers
Modify and Conduct New Trial

them. Family farms/businesses and business/corporate farms are less likely to develop them than less complex/divergent innovations, but are still assumed to give them strong consideration. It is emphasized that these models are presented for illustration--similar models could be constructed comparing innovations according to other attributes, for example impact on labor requirements or effectiveness.

The adoption of agricultural innovations is generally assumed to be driven by the decisions and actions of business/corporate farms and family farms/businesses. They are more likely to be on a sound financial base and to have access to additional funds through loans. Also, they have been shown to be highly mechanized (an indication of innovation) and to be strongly involved with various information sources and networks (i.e. they have the funds to purchase computers, travel to meetings, etc.). In addition, because of the size of their operations and their more extensive and powerful network links, these farm managers are more likely to be able to influence the external infrastructure and create an institutional environment compatible with the innovation.

Based upon the economic/social/political factors, farm characteristics, and farm owner/manager characteristics, the farmer will evaluate available information to determine whether an innovation will be cost-effective, compatible with the commodities being produced and the farm operation, and feasible within the existing institutional context and based upon his/her values will determine whether to implement the innovation. If the innovation is not implemented, the farmer may wait for further information and then go through the decision process again, or may wait for the introduction of an alternative innovation (in reality, they are likely to be considering several innovations at one time and to have several innovations at various levels of adoption on their farm). It is always assumed that if an innovation is implemented its performance will be evaluated to determine whether its implementation will be continued, expanded, reduced, or discontinued.

If the evaluation is positive, the farmer is likely to continue or increase use of the innovation and inform other farmers of the positive results. If the evaluation is negative, the farmer is likely to either stop using the innovation and inform other farmers of the negative results or try to determine whether the innovation should be tried again after being modifying or when relevant economic factors and/or farm and owner/manager characteristics change. In either situation, the owner/operator will go through this decision-making process again as new innovations are proposed. Information exchange is assumed to be between family farms/businesses and business/corporate farms. It should be noted, however, that little data are available on the interaction/information exchange networks within and between different types of farm operations.

Family farms are assumed to be less likely (as signified by the dashed line) to independently adopt innovations, even if they are relatively simple and do not diverge significantly from existing farm operations, because they are likely to represent a greater

degree of risk for the farm enterprise. However, once additional information is received about the innovation (from the family farms/businesses and the business/corporate farms) the sense of risk may be diminished and they are then more likely to adopt the innovation. The remainder of the decision-making process then proceeds as described above, with the exception that family farmers may be less likely to modify an innovation and try it again because the initial investment may have been the only discretionary funds available for such trials. Part-time/small farmers are assumed to be the similar to family farms in the adoption of less complex and divergent innovations.

As stated above, the decision-making process for more complex and divergent innovations is generally similar. The notable exceptions are that hobby/small farmers may not have the financial resources to implement the more costly and divergent agricultural innovations. Also, the family farmers are not likely to implement these innovations because of the greater management cost and risk associated with them, relative to their operations. The remaining two types of farms may still adopt the innovation on a trial basis but will certainly scrutinize them much more closely because of the higher perceived risk factor.

In the case of irrigation and drainage management innovations, farmers in the San Joaquin Valley are faced with an even more complex problem of deciding among an array of recommended innovations. The literature reviewed provides little insight into the factors that influence farm owners'/managers' choice of one potential innovation over other alternatives.

Little information could be found delineating the irrigation/drainage technologies and practices adopted by farmers in the westside under specified conditions. Without these data on local adoption practices, it is difficult to accurately determine what factors may presently be affecting adoption of irrigation/drainage innovations in the San Joaquin Valley. Without such information there is no firm basis for limiting the number of innovations to be investigated to determine social impacts or to anticipate which types of farms will select which types of irrigation and drainage management innovations. The SJVDP results of the Dinar and Campbell survey (forthcoming) will, therefore, be particularly useful in illuminating the patterns of innovation adoption across farm types.

3.0 EVALUATION OF PROPOSED IRRIGATION AND DRAINAGE TECHNOLOGIES AND MANAGEMENT PRACTICES

A number of irrigation technologies and management practices have been identified as potentially beneficial in reducing the agricultural drainage problems in the San Joaquin Valley. A number of these were studied by Burt and Katen (1988:21) during 1986-87 in the Westside Resource Conservation District and the Westlands Water District. In this study, a cost-sharing program was developed with individual growers who tried new irrigation practices and technologies. Evaluations were made of past irrigation practices, pre-irrigation, regular irrigation, and final performance and success. The program was found to be very popular, and provided an assessment of the success of the innovations. The users then evaluated each of the alternatives by assigning them three levels of priority recommendation. These three levels were weighted according to priority (first priority=3 points, second priority= 2 points, and third priority=1 point). These options are summarized in Table 1, as a result of extensive study, the planning team has developed a set of drainage technologies and management practices that are recommended for consideration by farm operators and water district managers in the San Joaquin Valley. These alternatives are shown in Table 2. It is worth noting that there is a significant difference between the alternatives identified for irrigation (Table 1) and for drainage management (Table 2) in the degree of individual farm owner/manager control over implementation. In general, the drainage management alternatives require considerably greater coordination with other farmers and other organizations than do the irrigation alternatives. These two sets of innovation recommendation are used here to illustrate an approach to evaluating such options that takes into account the complex interrelationships among the social/institutional/political factors; farm characteristics; farm manager characteristics; and technology characteristics shown in the literature to be important.

At this time, inadequate data exists to determine which innovations are most likely to be accepted by farmers and to be successful. The methodology proposed here may be useful for evaluating the likelihood of adoption and assessing the impacts of potential technologies/practices on the farm operation as additional information becomes available.

Two sets of evaluation matrices have been developed (one for each set of recommended innovations) and are presented in Tables 3 and 4 as a prototype for use in determining potential innovation adoption and impacts. Each matrix presents the key variables identified in the literature and model along one axis and proposed innovations along the other. With this approach, a form would be filled out for each type of farm and crop for which the innovation is proposed. The type of crop being grown is important because the technology must be compatible with it and because varying levels of success have been demonstrated between certain technologies and crops.

Table 1. Prioritized Irrigation Options--Burt and Katen

Technology	Points	Rank
Reduce furrow length	85	1
Increase flow rate, reduce set times	54	2
Use surge valve system	46	3
Use torpedo in furrows	34	4
Improve use of tailwater return system	29	5
Improve placement of sprinkler mainlines	28	6
Install tailwater return system	25	7
Use sprinklers for pre- and germination irrigation	19	8
Irrigate alternate furrows early in season	18	9
Increase advance rate	16	10
Coordinate early irrigation with fertilization	15	11
Retain professional irrigation engineer	15	
Install gated pipe in place of open ditches	15	
Improve uniformity of sprinkler equipment	14	14
Increase sprinkler operating pressure	9	15
Use soil amendments/deep ripping	9	

Source: Burt and Katen 1988:21.

Table 2. Drainage Management Practices and Technology Alternatives

Technology

- Drainage - Water Treatment
  - Anaerobic - Bacterial Treatment
  - High-Rate Algae Ponds
  - Ferrous Hydroxide Treatment
  - Reverse Osmosis
- Subsurface Drainage - Water Reuse for Agriculture
- Concentrate Drainage Water in Solar Ponds for Energy Production
- Evaporation Ponds
- Deep Percolation into the Semi-Confined Aquifer
- Injection into Deep Geologic Formations
- Discharge with Dilution

Source: San Joaquin Valley Drainage Program, 1989, Draft Preliminary Planning Alternatives. Sacramento, CA.

First, the existing data about each innovation needs to be summarized, with assumptions made where data is not available. The summary can either be presented in a narrative form or in a table. The data and assumptions can each be classified independently (high, medium, or low) or rank-ordered in relation to others (so that a comparison is created between assumed properties). The former method is preferred and recommended for this evaluation because enough information may not exist to rank each innovation on each key variable. Where possible, assumptions about the relative weights of each key variable should also be presented.

The matrix would be filled out with each cell receiving a plus (+), zero (0), or a minus (-). Pluses are used when the positive characteristics of an innovation for a key variable outweigh the negative characteristics for that variable (because few innovations are totally positive or negative on a single variable). A zero is assigned when the positive

Table 3. Matrix for Evaluating Irrigation Adoption Options

FARM TYPE:________________ CROP TYPE:________________

Factors Affecting Adoption	Social/Institutional/ Political Factors						Farm Characteristics								Farm Owner/Manager Characteristics						Technology/Management Practice Characteristics											
Potential Technologies and Practices to be Implemented	Cost & Price Structure of Water & Drainage	Stability/Reliability of Water Sources	Financial Infrastructure	Information Exchange Networks/ Technical Assistance	Complexity of Water & Drainage Management Agreements	Environmental Regulations/ Standards	Type & Amount of Crops Grown	Land Characteristics & Soil Types	Existing Technologies & Practices	Size of Farm	Number of People Employed	Farm Assets & Indebtedness	Source of Water	Severity of Drainage Problem	Decision-Making Process	Educational Level & Participation in Information Networks	Number of Years in Farming	Perception of Needs, Effects, and Benefits	Long-Term Familial Operation	Value Structure	Level of Demonstrated Success	Compatibility with Existing Equipment Practices	Reliability & Complexity of System	Capital Requirements	Labor Requirements	Operation & Maintenance Costs	Convenience & Timing of Use	Nature of Problems Created by Technology	Pluses	Balanced Impact	Negatives	Totals
1. Reduce Furrow Length																																
2. Increase Flow, Reduce Time																																
3. Surge Valve System																																
4. Torpedo in Farrows																																
5. Use Tailwater System																																
6. Improve Sprinler Placement																																
7. Install Tailwater System																																
8. Sprinklers for Pre-Irrigation and Germination																																
9. Irrigate Alternate Furrows																																
10. Increase Advance Rate																																
11. Coordinate Irrigation Fertilization																																
12. Professional Irrigation Engineer																																
13. Gate Pipes																																
14. Improve Sprinkler Uniformity																																
15. Increase Sprinkler Pressure																																
16. Soil Amendments/Deep Ripping																																
Totals																																

Table 4. Matrix for Evaluating Drainage Adoption Options

FARM TYPE:____________________ CROP TYPE:____________________

Factors Affecting Adoption	Social/Institutional/ Political Factors						Farm Characteristics								Farm Owner/Manager Characteristics						Technology/Management Practice Characteristics											
Potential Technologies and Practices to be Implemented	Cost & Price Structure of Water & Drainage	Stability/Reliability of Water Sources	Financial Infrastructure	Information Exchange Networks/ Technical Assistance	Complexity of Water & Drainage Management Agreements	Environmental Regulations/ Standards	Type & Amount of Crops Grown	Land Characteristics & Soil Types	Existing Technologies & Practices	Size of Farm	Number of People Employed	Farm Assets & Indebtedness	Source of Water	Severity of Drainage Problem	Decision-Making Process	Educational Level & Participation in Information Networks	Number of Years in Farming	Perception of Needs, Effects, and Benefits	Long-Term Familial Operation	Value Structure	Level of Demonstrated Success	Compatibility with Existing Equipment Practices	Reliability & Complexity of System	Capital Requirements	Labor Requirements	Operation & Maintenance Costs	Convenience & Timing of Use	Nature of Problems Created by Technology	Pluses	Balanced Impact	Negatives	Totals
1. Drainage - Water Treatment																																
2. Anaerobic - Bacterial Treatment																																
3. High-Rate Algae Ponds																																
4. Ferrous Hydroxide Treatment																																
5. Reverse Osmosis																																
6. Subsurface Drainage - Water Reuse for Agriculture																																
7. Concentrate Drainage Water in Solar Ponds for Energy Production																																
8. Evaporation Ponds																																
9. Deep Percolation into the Semi-Confined Aquifer																																
10. Injection into Deep Geologic Formations																																
11. Discharge with Dilution																																
Totals																																

and negative characteristics are equal and a minus is used when the negative characteristics outweigh the positive ones. The evaluation system can be given greater flexibility by using more symbols, if greater precision is required. The total number of each type of symbol can then be tabulated for the key variables and innovations to determine which innovations are most likely to be adopted for that type of farm and crop, and to show which variables had the most positive and negative characteristics. A numeric score can be assigned to each innovation by assigning each positive a one (1), using a zero as is, and assigning a negative one (-1) for each minus.

This system provides a comprehensive, documented, trackable, revisable system for attempting to make preliminary estimates about the success of implementing an innovation under a given set of circumstances. It will indicate where information is required (because of the assumptions that are made), it can be reviewed and revised as necessary, and will provide a basis for evaluating the decision-making model. The evaluation matrix can also suggest what promotional efforts may be most successful for particular innovations. For instance, the model states that the corporate and family/business farmers will be the first and primary implementors. When this is considered in conjunction with the fact that a small number of these types of farms account for a majority of the land under cultivation, the most efficient programmatic response (providing the best results with the smallest expenditures) would be to promote the positive features of innovations targeted for that group.

4.0 BACKWARD MAPPING: AN APPROACH TO THE ANALYSIS OF POLICIES AND STRATEGIES TO ENCOURAGE ADOPTION AND DIFFUSION OF RECOMMENDED INNOVATIONS

Implicit in the identification of recommended irrigation and drainage management practices and innovations is the goal of encouraging their adoption and use. An understanding of the factors affecting adoption and diffusion of innovations is critical not only to the development of "appropriate" innovations, but to the development of strategies to encourage a greater proportion of farm owners/managers to adopt these innovations and to adopt them sooner rather than later. Efforts to affect the rate and pattern of adoption of recommended innovations falls within the category of implementation. This paper provides information that is useful not only to anticipate the patterns and rates of adoption innovation, but also to inform efforts to alter those patterns and rates so that the outcome is more consistent with policy objectives.

An analytic technique developed by Richard Elmore (1980), called "backward mapping," has gained recognition as a useful approach to implementation analysis. It is particularly applicable to the problem of influencing irrigation and drainage management through adoption of innovative technologies and practices. Elmore developed this approach as an alternative to the more common "forward mapping," which starts with the policy statement and objective and systematically identifies the sequence of increasingly specific steps that would need to be taken by those responsible for implementing the policy to achieve the desired outcome. As summarized by Elmore (1980: 603):

> Forward mapping of a federal policy might begin with a statement of congressional intent. It would then outline federal agency regulations and administrative actions consistent with that intent. It would elaborate a division of responsibilities between central and regional offices of the federal government (or among federal, state, and local administrators) such that each implementing unit had a clearly defined mission. It would then state an outcome, usually in terms of an observable effect on a target population, consistent with the initial purpose of the policymakers.

Backward mapping was developed to reflect more accurately the actual process of policy and program implementation, a process in which policymakers exercise less than complete control.

> The logic of backward mapping is, in all important respects, the opposite of forward mapping. It begins not at the top of the implementation process but at the last possible stage, the point at which administrative actions intersect private choices. It begins not with a statement of intent, but with a statement of the specific behavior at the lowest level of the implementation process that generates the need for a policy. Only after that behavior is described does the analysis presume to state an objective; the objective is first stated as a set of organizational operations and then as a set of effects, or outcomes, that will result from these operations.

> Having established a relatively precise target at the lowest level of the system, the analysis backs up through the structure of implementing agencies, asking at each level two questions: What is the ability of this unit to affect the behavior that is the target of the policy? And what resources does this unit require in order to have that effect? In the final stage of analysis the analyst or policymaker describes a policy that directs resources at the organizational units likely to have the greatest effect.
>
> Although backward mapping takes the policymaker's perspective on the implementation process, it does not assume that policy is the only-- or even the major-- influence on the behavior of people engaged in the process. Furthermore, it does not rely on compliance with the policymaker's intent as the standard of success or failure. It offers instead a standard of success that is in all respects *conditional*; that is, one's definition of success is predicated on an estimate of the limited ability of actors at one level of the implementation process to influence the behavior of actors at other levels and on the limited ability of public organizations as a whole to influence private behavior.
>
> Forward mapping assumes that organizational units in the implementation process are linked in essentially hierarchical relationships. This assumption has two corollaries: the closer one is to the source of the policy, the greater is one's authority and influence; and the ability of complex systems to respond to problems depends on the establishment of clear lines of authority and control. Backward mapping assumes essentially the opposite: the closer one is to the source of the problem, the greater is one's ability to influence it; and the problem-solving ability of complex systems depends not on hierarchical control but on maximizing discretion at the point where the problem is most immediate. (Elmore 1980: 604-605.)

Elmore points out that forward and backward mapping techniques yield significantly different results. Analyses using forward mapping tend to stress factors that lead to centralization of control and that are readily manipulated by policymakers. Analyses using backward mapping, conversely, tend to stress decentralization of control and to focus on factors such as knowledge, problem-solving ability among lower level administrators, incentive structures that directly affect the target population, and the strategic use of resources to affect discretionary choices. Given the nature of the irrigation and drainage management problems in the westside of the San Joaquin Valley and the critical role played by farm owners/managers and water and drainage management districts in addressing the agricultural drainage problem, backward mapping appears to be a particularly appropriate analytic approach.

Backward mapping "focuses on the *process* by which organized problem-solving occurs and the *output* that results from problem solving" (Elmore 1980: 607). The approach seeks to "identify the one or two critical points in a complex organization that have the closest proximity to the problem and describ[e] what needs to happen at those points to solve the problem" (Elmore 1980: 607). Backward mapping reflects the findings of the implementation literature by providing an analytic framework that:

> "takes account of reciprocity in the relationship between superiors and subordinates in organizations; the connection between hierarchical control and increased complexity; discretion as an adaptive device; and bargaining as a precondition for local effects" (Elmore 1980: 612).

When applied to the agricultural drainage problem, the technique of backward mapping encourages the development of a clearer picture of what transactions are critical to successful management of agricultural drainage, and a better appreciation of the information needed to understand and influence those transactions. This paper is only a first step in this process. The technique of backward mapping helps formulate questions that remain to be answered before an effective strategy to encourage more widespread and rapid adoption of recommended irrigation and drainage management technologies and practices can be formulated– or indeed before it can be determined that such a strategy is needed. Among these questions are:

- Are the typologies of the farm accurate and are they helpful in identifying factors that result in differential patterns of innovation adoption or that affect implementation strategies?
- Are the key variables identified from the literature review applicable to farming and farmers in the San Joaquin Valley (particularly because the literature indicates significant variation between geographical area, innovations, and existing farm characteristics)?
- What types of farms are currently using the proposed innovations and what led farmers to adopt them? Are these innovations having the desired policy effects?
- What are the attributes of the primary technologies and management practices currently being proposed for adoption in the San Joaquin Valley that make them attractive or problematic to different types of farm owners/managers? Can these technologies and practices be modified to make them more attractive and easier to implement? Who would do this modification?
- What are the points of intervention available to the drainage program that could be used to encourage adoption of recommended practices and technologies? What incentives or assistance would be effective? Are incentives or assistance needed? Who can provide it?
- What future circumstances are likely to arise which would affect the economic factors (particularly farm subsidy programs, crop prices, and water/drainage costs), farm characteristics, or would significantly improve the attractiveness of one innovation over another innovation?

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